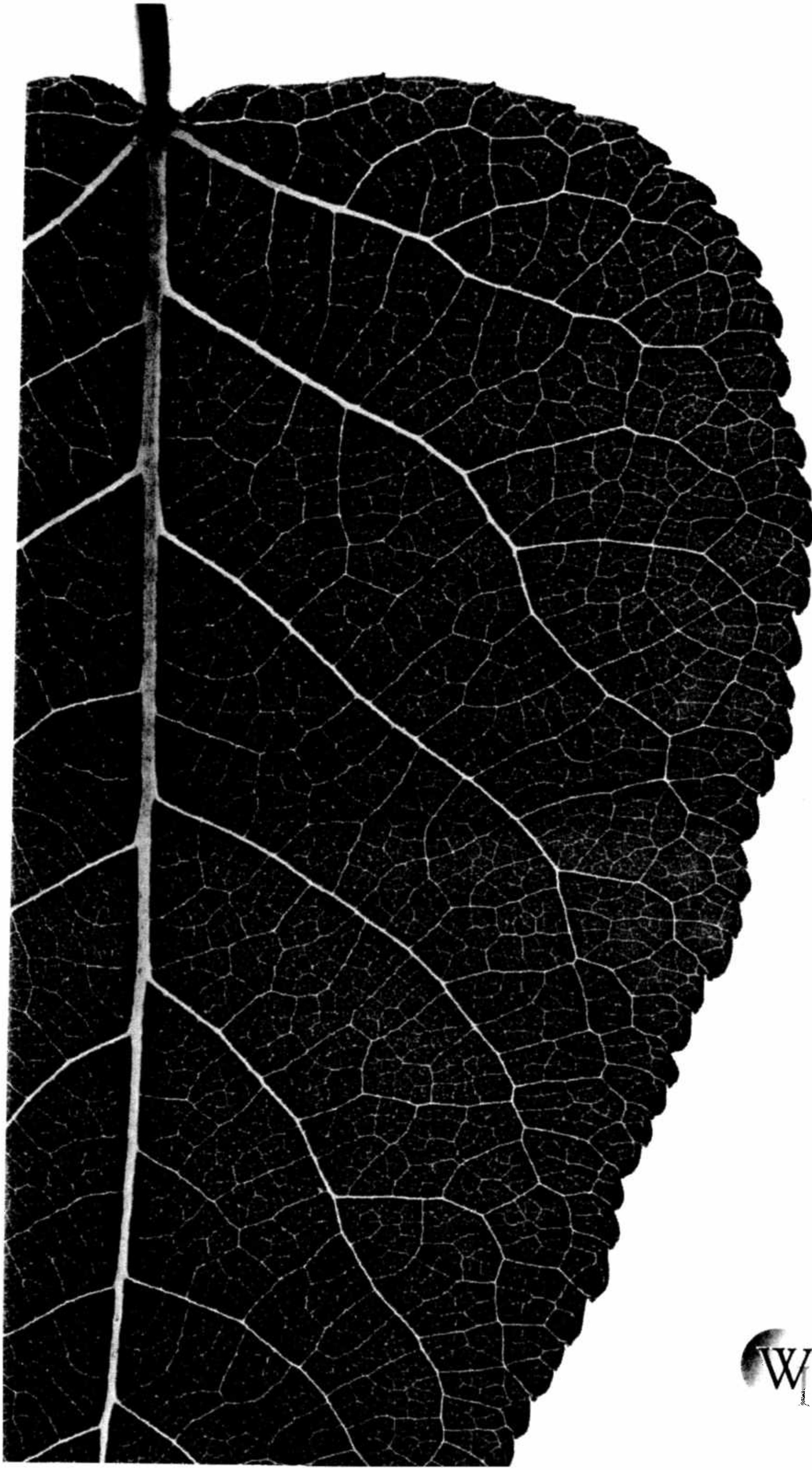

Smart Choices for Biofuels

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This report is a joint project of the Worldwatch Institute and the Sierra Club.
Both organizations share the views and policy recommendations expressed in the report.

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The Worldwatch Institute is an independent, international research organization that provides compelling, accessible, and fact-based analysis of environmental, resource, and economic problems. Worldwatch focuses on the underlying causes of and practical solutions to the world's problems in order to inspire people to work for a sustainable future.

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*On the cover: Researchers at the Joint Genome Institute led the effort to successfully sequence the genome of the poplar (*Populus*) tree. They now have the candidate genes that will help domesticate poplar for biomass and reduce the cost from $50 to about $20 per ton, a boon to potential future production of biofuels.*
Photo courtesy Lawrence Berkeley National Laboratory

[for the grass cover]
On the cover: The fast-growing Asian grass Miscanthus *is being tested as a possible biofuel source.*
Photo by westpark

January 2009

Smart Choices for Biofuels

Introduction

Much of the strong support for biofuels in the United States is premised on the national security advantages of reducing dependence on imported oil. In late 2007, these expected payoffs played a major role in driving an extension and expansion of the national Renewable Fuels Standard in the U.S. Energy Independence and Security Act, which calls for the use of 36 billion gallons of biofuels nationwide by 2022.

Worldwide, efforts to replace oil with biofuels are at a critical juncture. Double-digit growth in ethanol and biodiesel use during the past three years has contributed to a rapid increase in food, feed grain, and soybean prices, as well as a sharp environmental backlash. Evidence is building that the biofuels industry is creating a host of ecological problems while failing to deliver real reductions in greenhouse gas emissions. Demand for biofuels is also creating global pressure for carbon-emitting deforestation and land conversion, as food and fuel compete for scarce resources.

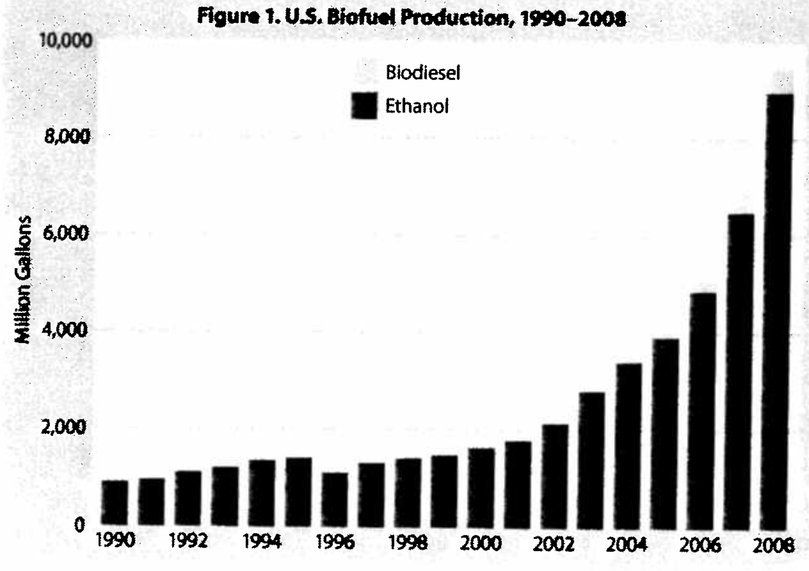
Over the next decade and beyond, U.S. national, state, and local policy must focus on developing sustainable biofuels—rather than just more biofuels—that can play a role in the emerging new energy economy. These fuels should be seen as part of an expanded renewable energy portfolio that emphasizes greater fuel efficiency and reduced demand as well as the development of new sustainable energy technologies that may one day go beyond biofuels. But this red, white, and green path can only succeed if we avoid the mistakes of the past.

Biofuels Today

The two most common biofuels in the United States today are ethanol and biodiesel, with corn-based ethanol leading by a wide margin. These biofuels are not used in isolation but are instead blended into conventional fuels, with ethanol mixed into gasoline and biodiesel blended into petroleum diesel. (See Sidebar 1.)

The growth in U.S. ethanol production over the past few years dwarfs other transportation fuel options that are increasingly available or are nearing commercial production. This outcome was driven in part by the substitution of ethanol for MBTE, a gasoline additive that was found to be a major source of groundwater contamination. It was also a response to recent high oil prices and to the political popularity of ethanol's perceived contributions to energy secu-

Figure 1. U.S. Biofuel Production, 1990–2008



Sidebar 1. Biofuels Basics: Understanding Biomass, Bioenergy, and Biofuels

Biofuels include ethanol, biodiesel, ethyl tertiary butyl ether (ETBE), butanol, and others. At the moment, most of these fuels are made from three kinds of agricultural feedstocks, which are also used for food:

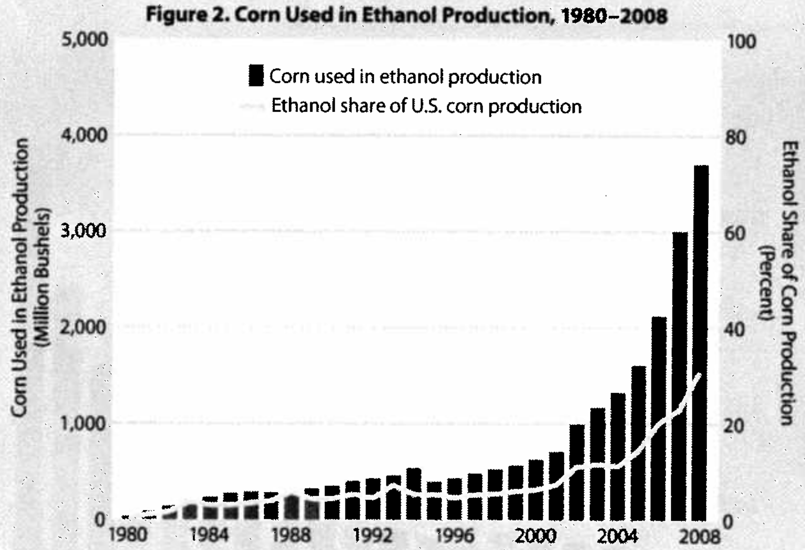
- sugar crops, including sugar cane, sugar beets, and sweet sorghum;
- starch crops, including corn, wheat, barley, rye, cassava, sorghum grain, and other cereals; and
- oilseed crops, including rapeseed/canola, soybeans, sunflower, mustard, and others.

Bioenergy is energy derived from "biomass," or any kind of plant or animal matter. The most traditional source of bioenergy is fuel wood or animal dung, burned in open fires for heating and cooking. In the United States, "biofuel" refers most often to liquid fuels for transportation, whereas "bioenergy" is commonly used to describe electricity or thermal energy generated from renewable biomass sources. Two modern ways to produce energy from biomass are to burn it directly in furnaces and gasifiers and to ferment biomass to produce biogas.

Biofuel production uses both old and new technologies. Conventional "first-generation" ethanol is made by fermenting sugars from plants with high starch or sugar content into alcohol, using the same basic methods that brewers have relied on for centuries. The purest form of biodiesel is straight vegetable oil, but a more refined form uses a fairly simple process called transesterification to produce methyl esters (basically, diesel).

"Second-generation" biofuel technologies employ more sophisticated processes to convert biomass into fuel. These include enzymatic and other processes to convert cellulose from grasses and waste wood into ethanol and other fuels, and to process animal waste and fat, algae, and urban wastes into biodiesel. Other technologies produce not only ethanol and biodiesel, but also bio-butanol, methanol, liquid hydrogen, bio-gasoline, and synthetic diesel.

Figure 2. Corn Used in Ethanol Production, 1980–2008



rity and rural development.

In 2008, U.S. production of corn ethanol reached an estimated 9 billion gallons, a relatively small amount compared to the 390 billion gallons of motor gasoline consumed in the country every day.[1] (See Figure 1.) The U.S. Department of Agriculture (USDA) projects that nearly one-third of the nation's corn crop will be used to produce ethanol by 2009–10.[2] (See Figure 2.) By volume, however, ethanol is projected to constitute only some 8.5 percent of annual U.S. gasoline use by 2017.[3]

Biodiesel production has lagged behind ethanol, although the industry has also expanded rapidly in the last decade. U.S. biodiesel is produced mainly from soy or waste cooking oil, although some producers are using canola or cottonseed oil.[4]

In January 2008, there were 171 biodiesel plants nationwide—similar to the number of ethanol plants—but their combined annual capacity was only 2.3 billion gallons.[5] Actual biodiesel production in 2007 was only 450 million gallons, compared to the 6.5 billion gallons of ethanol produced that same year.[6] Over the last two years, biodiesel production has lagged significantly behind capacity; even so, another 1.1 billion gallons of capacity is slated to come online by mid-2009.[7]

Both corn and soybeans experienced rapid and dramatic price increases in recent years as these commodities attracted investments, as oil prices rose, and as the U.S. dollar declined in value. However, high demand triggered by biofuel mandates also contributed significantly to the price increases.[8] These increases have caused hardship for other agricultural sectors such as livestock and poultry, since corn is a valuable component of animal feed. The USDA projects high price levels to be maintained to 2017.[9]

Worldwide, ethanol production grew from 7.8 billion gallons in 2000 to an estimated 20.9 billion gallons in 2008.[10] Brazil is the biggest ethanol producer after the United States, producing most of its ethanol from sugar cane. World biodiesel production has also grown rapidly as more countries adopt mandates to use a percentage of biofuels in their domestic energy supplies.

The Effects of First-Generation Biofuels

Despite ambitious government mandates and strong financial support for the biofuels industry, so-called "first-generation" biofuels have raised a variety of economic, social, and environmental concerns. New information points to the urgent need for a major shift to more advanced biofuels to prevent negative effects on the climate, land, soil, water, air, and rural economies.

Climate. Producing and using first-generation biofuels can release more greenhouse gases than are absorbed during biomass growth. These emissions occur when new land is cleared for cultivation; when fertilizer and pesticides are manufactured, transported, and applied; when energy is used to run farm machinery, pump irrigation water, and operate refineries; and when the fuel is transported and used. The total global warming footprint depends on what feedstock is used, how and where this feedstock is grown, any land-use changes, and how the fuel is processed. Scientists disagree about the potential benefits of corn ethanol; some estimates suggest that it provides a 12 to 18 percent net reduction in emissions compared to gasoline, but these figures assume that the refineries are fueled by natural gas.[11] If more-polluting coal power is used, the lifecycle emissions are *higher than* those associated with gasoline.[12] (See Sidebar 2.)

Land, soil, and conservation. The corn ethanol boom poses a particular threat to the U.S. Conservation Reserve Program (CRP), which encourages farmers to "set aside" or retire their marginal lands from production as a way to curb soil erosion, improve wildlife habitat, and restore watersheds.[13] Some surveys indicate that CRP land was reduced by 16 percent in 2007 alone, and an additional 28 million-plus acres are set to expire by 2010.[14] With rising demand for corn, landowners will have a continued economic incentive to return much of this land to production.

Water. A report from the U.S. National Academy of Sciences concludes that producing up to 15 billion gallons of corn ethanol annually will result in considerable harm to the nation's water quality, mainly from increased nitrogen and phosphorous pollution.[15] Other research has estimated that the increase in corn production in 2007 alone would cause total nitrogen runoff to rise by 2.3 percent, further adding to the problem of "dead zones" in the Gulf of Mexico and other water bodies like the Chesapeake Bay.[16] Corn ethanol is also very water intensive, not just at the refinery stage, where each gallon of fuel produced requires 3–4 gallons of water, but also in the field.[17] A growing concern is the depletion of non-renewable aquifers, such as the Ogallala Aquifer, which provides irrigation for much of the southern Great Plains.[18] As many as nine new ethanol refineries are slated for construction above the Ogallala, including in areas where the water table has already dropped significantly.[19] The increase in water demand from these refineries alone is expected to be 2.6 billion gallons annually, equivalent to the water consumption of 70,000 average Americans.[20]

Air pollution. Biofuel production, refining, and burning emit a variety of air pollutants in addition to greenhouse gases, such as smog-forming compounds and particulates. In April 2007, the U.S. Environmental Protection Agency relaxed the rules for ethanol

Sidebar 2. Why Corn Ethanol Isn't Necessarily Climate-Friendly

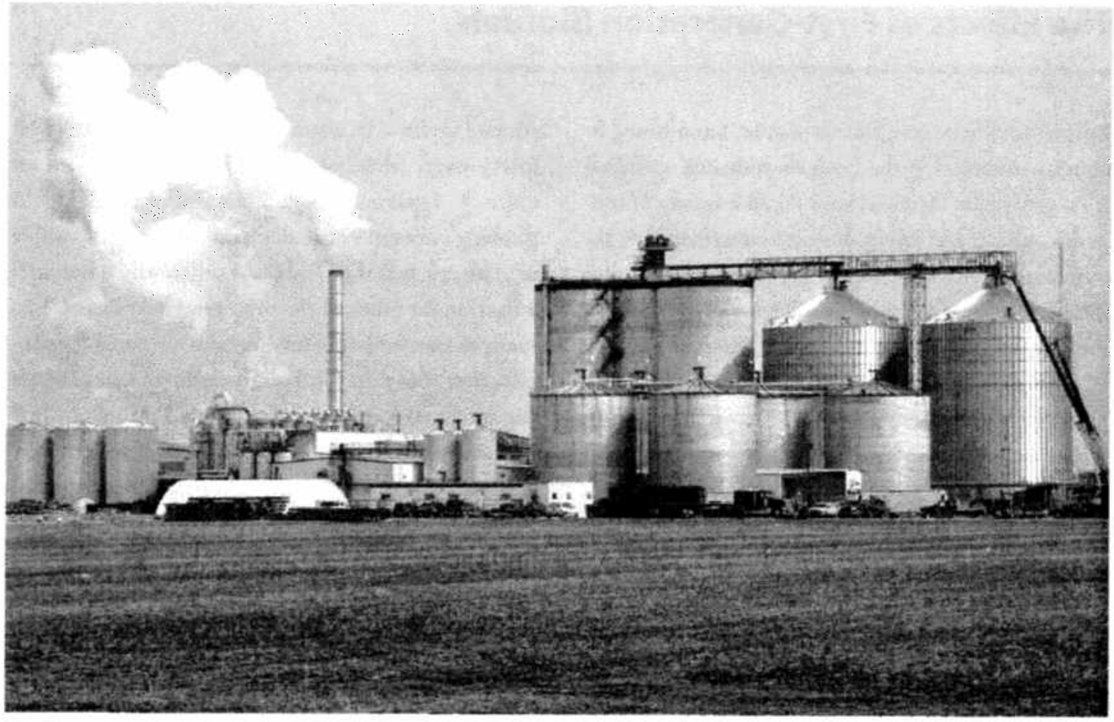
The climate impact of biofuels depends in large part on how the feedstock is managed and what kind of land is used to produce it. A 2006 study from the University of California at Berkeley concluded that each acre of corn feedstock generates the equivalent of 2.7 tons of carbon dioxide emissions each year. The study found that, on average, nearly 40 percent of these emissions occur during the agricultural phase of production, three-quarters of which are from the use of inorganic fertilizer. Producing and transporting fertilizer requires large amounts of fossil fuel, and nitrogen fertilizer itself degrades into nitrous oxide, a potent greenhouse gas.

Because corn depletes soil nutrients, it is typically rotated annually with a legume crop, such as soybeans, to restore soil nitrogen levels. In 2006 and 2007, however, many U.S. farmers chose to skip this rotation because it appeared to be more profitable to produce corn. When corn is grown more intensively, more chemical inputs must be applied.

Global warming impacts from farming also occur when soils degrade over time and lose their organic carbon stores, including during tilling. Corn cultivation in particular has been criticized for reducing soil carbon. This concern is especially salient when corn production moves onto land that has been set aside for conservation.

During ethanol refining, as much as 90 percent of the lifecycle greenhouse gas emissions can come from powering the process with natural gas. For ethanol plants that burn coal, this use of coal power accounts for nearly 100 percent of the emissions in the refining stage. Unfortunately, as natural gas prices have climbed, ethanol refineries have turned increasingly to coal as a cheaper energy source.

Sources: See Endnote 12.



Ethanol plant in West Burlington, Iowa.
Photo by Steve Vaughn

refineries, allowing them to double their emissions of certain regulated air pollutants.[21] All of these pollutants are known to harm human health, including particle pollution, ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. Additionally, some research indicates that compared to gasoline, high-level ethanol blends may increase the formation of ground-level ozone, which contributes to smog and is linked to some human illnesses.[22]

Economics, markets, and prices. Evidence suggests that the economic benefits of an expanding biofuel industry have not been as great in some U.S. rural communities as originally estimated. Although farmers benefited initially from stakes in ethanol cooperatives, the trend is toward industry consolidation and the transfer of locally owned biofuel plants to large agribusiness companies.[23] Moreover, corn prices in 2007–08 rose so dramatically that some ethanol refineries had problems with supply; as food prices increased in the United States and abroad, livestock and poultry producers argued that they could not afford to compete for corn supplies. When oil prices started to fall in late 2008, some large ethanol plants that had bet on continuation of high energy prices announced they were going out of business.[24]

Job creation. Many communities have found that initial estimates of biofuels' job creation benefits—for example, 700 permanent jobs in an area near an ethanol plant—were overblown.[25] More realistic estimates are that 130 to 150 jobs may be created from such facilities when the economy is good.[26] However, this does not include job losses in the livestock industry as corn is diverted from animal feed to ethanol.

The Next Generation: Advancing Biofuels

Nearly all studies on the role of biofuels in mitigating global warming and boosting energy security have concluded that "second-generation" (or "advanced") biofuels, which rely on non-food feedstocks and offer dramatically improved energy and greenhouse gas profiles, are necessary to make wider use of biofuels feasible worldwide.

Cellulosic technology is one of the most commonly discussed second-generation biofuel technologies in the United States. Cellulosic biofuels are derived from the cellulose in plants, some of which are being developed specifically as "energy" crops rather than for food production. These include perennial grasses and trees, such as switchgrass, which is native to the United States and has received considerable attention nationwide. A variety of other grasses is also being tested, including blue grass, gammagrass, and the tropical Asian grass *Miscanthus*.[27] At the moment, an estimated 55 cellulosic refineries are planned, under construction, or operating in 31 states.[28] Most are expected to begin operations in 2010 or 2011, but only a few plan to operate at a commercial scale.

The potential yields of cellulosic feedstocks differ greatly, as do their environmental and energy profiles. U.S. test plots planted with switchgrass have yielded enough biomass to produce nearly 1,200 gallons of ethanol per acre annually, using fewer energy inputs than corn.[29] (In contrast, a bumper crop of 180 bushels of corn per acre will provide less than 500 gallons of fuel.[30]) In practice, however, it makes sense to grow switchgrass and other perennial biofuel crops on more marginal lands than in the test plots, and in dryer and colder climates, to avoid competition for good farmland. Under these conditions, the grasses will produce less than 500 gallons an acre, and perhaps as little as 300 gallons, unless yields are improved with breeding.[31] The real benefit of the grasses, however, is not in their yields but in the fact that they can be grown with relatively little energy input (including minimal inorganic fertilizer and pesticide use), with potentially positive effects on soil and water quality, and on lands where raising corn, soybeans, and other food crops would not be feasible.

Crop residues, in the form of stems and leaves, represent another substantial source of cellulosic biomass. Corn stover—the stalks and cobs that remain after harvesting—is often mentioned, but some studies suggest that removing even 25 percent of this material from fields will reduce soil quality and decrease carbon content, even on prime agricultural land.[32] Fast-growing trees like willow and poplars are also being considered for their cellulose content, although there are downsides when invasive tree species are used and when forest removal rates are excessive.

Other advanced biofuel feedstocks include non-plant sources such as fats, manure, and the organic material found in urban waste. In addition, algae production has great promise because algae generates higher energy yields and requires much less space to grow than conventional feedstocks.[33] Algae also would not compete with food uses and could be grown with minimal inputs using a variety of methods.

Second-generation biofuels bring advances in processing as well. For biodiesel, newer technologies abandon the reliance on natural oil feedstocks, allowing for larger-scale production, greater use of industrial and urban wastes, and the creation of synthetic fuels from a wider range of biomass. Some petroleum companies, such as Shell, BP, and ConocoPhilips, are investing in synthetic diesel produced from animal fat, slaughterhouse waste, and other biomass sources using a thermochemical platform.[34] (See Sidebar 3.)

Sidebar 3. Advanced Biofuels Processing

Broadly speaking, there are two main approaches to second-generation biofuels production, known as the "biochemical platform" and the "thermochemical platform." Both of these can be used to produce a wide variety of fuels. In the biochemical platform, enzymes (biological catalysts, usually obtained from microorganisms) or acid are used to break down plant cell walls. These sugars are then fermented into alcohols (such as ethanol) by microorganisms, which are separated through distillation.

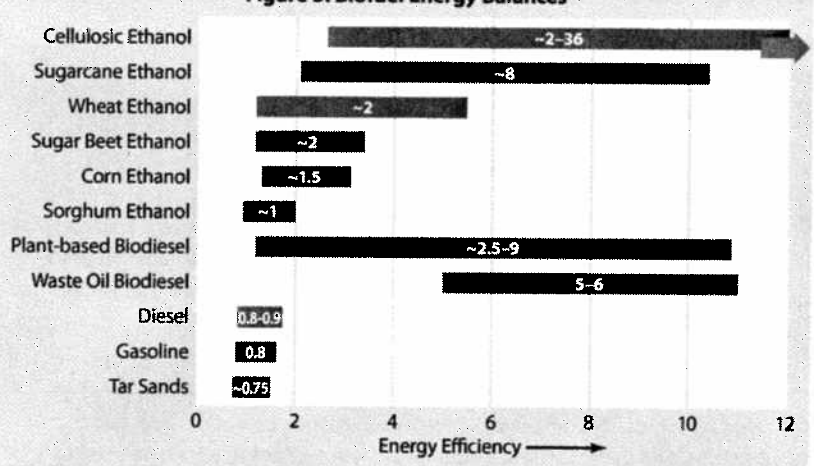
In the thermochemical platform, heat, pressure, chemical catalysts, and water are used to break down biomass in much the same way that petroleum is refined. Thermochemical technologies include gasification, fast pyrolysis, and hydrothermic processing. These technologies can be used to convert almost any kind of biomass into fuel, from grass to turkey feathers, giving them a potential advantage over biochemical technologies that rely on developing specific enzymes to break down specific plant matter.

Source: See Endnote 35.

There are several known ways to reduce the environmental footprint of both first- and second- generation biofuels. During the crop production stage, this includes minimizing the use of chemical fertilizers and pesticides and avoiding fragile land. Soybean and corn farmers are increasingly using no-till cultivation, whereby a crop is planted directly into the remaining residue of the last crop rather than on tilled, exposed soil. One-quarter of U.S. soybean producers and 10–20 percent of corn producers now use this technique, and it is practiced on about a quarter of the nation's cropland.[36] No-till cultivation reduces the greenhouse gas emissions at the farm level and is listed under the Chicago Carbon Exchange as a source of "carbon credits."

Improved management practices on farms that grow energy crops also include more efficient use of water, soil resources, and nutrients, and control of water effluent. Several programs enable U.S. farmers to measure their performance against production parameters, and there are many ongoing initiatives to develop voluntary sustainability standards for biofuels.[37] Even with more conventional biofuel technologies, it is possible to significantly reduce harmful effects by using other feedstocks that are more environmentally friendly.[38]

Figure 3. Biofuel Energy Balances



Note: Energy balance is a comparison of how much fossil energy goes into making a fuel against how much energy is provided by the fuel. The higher the energy balance, the more efficient the fuel. Figures provided above represent best estimates, not averages.

Refining biofuels using renewable and efficient energy sources can reduce environmental damage as well. Using renewable resources instead of natural gas or coal to provide heat and power for biofuel refineries would significantly lower greenhouse gas emissions. A 2007 analysis from the Argonne National Laboratory showed that refining corn ethanol in a facility fired by wood chips rather than fossil fuels could achieve emission reductions of 52 percent compared to gasoline.[39] Ethanol plants could also burn the byproduct distiller's grains as a process fuel to lower their emissions (though for now, the grains are more valuable as livestock feed).[40]

Climate. Cellulosic and other advanced biofuels have a better fossil energy balance than do first-generation biofuels; that is, the amount of fossil energy required to make the fuel is much lower relative to the amount of energy gained in return, which can significantly lower lifecycle greenhouse gas emissions.[41] (See Figure 3.) In the best-case scenarios, and using current technology, corn ethanol provides only about a quarter more energy than is invested (in worst-case scenarios, more energy is put into production than is returned).[42] In contrast, cellulosic ethanol will generate between 4 and 10 times more energy.[43]

Research shows that sustainable, low-input, and low-management switchgrass ethanol in three Midwestern states can yield 5.4 times more energy than invested, though it could be much higher.[44] Other research shows an energy balance of 9 for cellulosic ethanol—meaning that the useful energy provided by the ethanol is approximately 9 times the energy required to produce it.[45] Current estimates suggest that fueling our vehicles with cellulosic ethanol could reduce greenhouse gas emissions by 86–94 percent compared to gasoline, versus a reduction of only 12–18 percent for the best-performing corn ethanol.[46] (However, some studies show less promising results; the fact is that we do not yet know all of the effects because cellulosic ethanol is not yet widely produced at commercial scale.[47])

Moreover, the main cellulosic feedstocks being considered in the United States—perennial plants—can protect the soil and require little-to-no tilling, irrigation, or chemical inputs, all of which offer climate advantages. Cultivation of perennial feedstocks can even make a positive contribution to a biofuel's carbon balance.[48] Taking already degraded agricultural land or land planted with annual row crops and converting it to native grasses and trees would increase the carbon storage on that land. Research shows that some perennial biofuel crops like switchgrass may store enough carbon in the soil and their root mass to overcompensate for carbon released during the rest of the fuel's lifecycle, and could actually help take carbon dioxide *out* of the air.[49] Cellulosic biofuels may also offer an emissions benefit during refining, such as when byproducts such as lignin, rather than fossil fuels, are used to fuel processing.[50]

Land, conservation, and water. In a simulation of soil and water quality impacts over 20 years in a central Iowa watershed, a team of researchers found that planting all available land with switchgrass reduced sediment flows by 84 percent, nitrogen concentrations by 53 percent, and phosphorous by 83 percent.[51] Perennial crops such as switchgrass and other prairie grasses can be harvested annually with minimal increases in soil erosion, and if the grass is not cut too low, its removal can still allow habitat for small animals.[52]

Job creation. Because second-generation biofuel feedstocks and technologies do not rely exclusively on food crops or current technologies, they could have a positive economic effect on many communities not located near centers of food production or highly productive agricultural land. One study of potential job creation in renewable industries estimates that biomass will account for up to 30 percent of the more than 1.2 million jobs projected in renewable electricity generation by 2038, and alternative fuels will account for up to 23 percent of more than 1.4 million jobs in fuel production by 2038.[53] Another study estimates that investment in green jobs, including in the biomass sector, could create 1.5 million additional jobs.[54]

Beyond Biofuels

Today, we face the urgent need to reduce our energy use and diversify our energy supply as a way to lessen the risks from global warming and other environmental, security, and economic disasters. Based on current projections, no single renewable energy technology—including biofuels—will be able to compensate for all of our current and projected fossil fuel use. Too much reliance on imported oil has been disastrous, but so too would be overdependence on fuels from agriculture. Pushing biofuels beyond the limits of sustainability would undo all of their positive value, which forces us to look to other solutions "beyond biofuels."

One of the single biggest steps we can take to reduce our greenhouse gas emissions is to use technologies available today to lower overall fuel use. Cars, trucks, and other vehicles are responsible for more than a quarter of U.S. greenhouse gas emissions.[55] Meeting the new fuel economy standard of 35 miles per gallon in 2020 is expected to lower U.S. oil use by 1.1 million barrels a day in 2020 and by as much as 2.5 million barrels a day when fully phased in (or more if standards increase beyond 35 mpg).[56] Investments in public transportation and other alternatives to private vehicles could also help reduce demand.

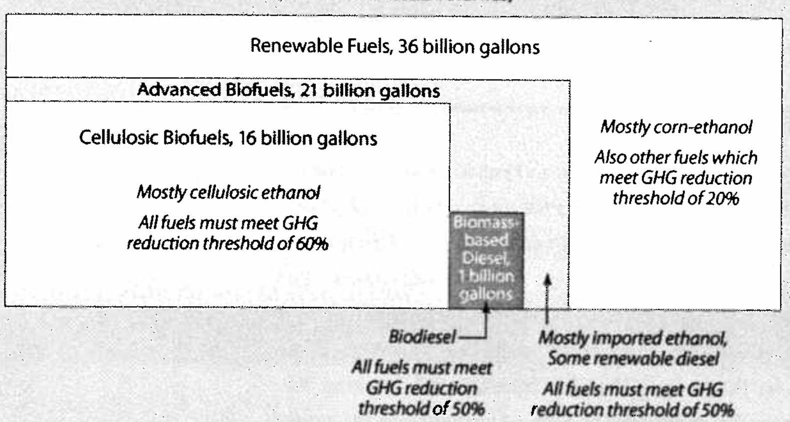
Converting biomass into heat or electricity instead of transportation fuel is a far more efficient use of this renewable resource, and some experts see biofuels as only a temporary bridge to more-efficient motor fuel technologies. Cellulosic ethanol is estimated to have a conversion efficiency of 35 percent.[57] Although this is a far better ratio than for corn ethanol, burning biomass for electricity or heating rather than for motor fuel offers conversion efficiencies of as high as 90 percent (versus 35–40 percent for traditional coal-fired power plants).[58] Because of these higher efficiencies, and because biomass can replace carbon-intensive coal for electricity, using biomass to produce liquid transport fuels is in fact a relatively expensive way to reduce greenhouse gas emissions.[59]

"Plug-in" hybrid electric cars, which could run on a combination of liquid biofuels and electricity from the grid, are one vehicle alternative that may be commercially available as early as 2009. If the electricity comes mainly from renewable energy sources, such as wind, hydropower, solar, or biomass combustion, plug-in hybrids could significantly lower their emissions compared to conventional cars and hybrids—without even using biofuels.[60]

In 2005, the United States adopted a national Renewable Fuels Standard (RFS) that started with a 4 billion gallon mandate in 2006 and increased to 7.5 billion gallons by 2012.[61] Congress later expanded the mandate in the 2007 Energy Independence and Security Act to a target of 36 billion gallons by 2022.[62]

The new law includes separate, nested mandates for different renewable biofuels. Corn ethanol, for example, can comprise only up to 15 billion gallons annually, while advanced biofuels increase from 600 million gallons in 2009 to 21 billion gallons annually by 2022; 16 billion gallons of this total must be cellulosic biofuel.[63] (See Figure 4.) The law is a blending mandate, requiring ethanol to be blended with gasoline.

Figure 4. The Standards are Nested
(Shown with 2022 volumes)



In addition to establishing a nearly fivefold increase over the original 2012 target, the new RFS includes building additional refinery capacity and infrastructure retrofits to accommodate ethanol transport and storage needs. It also funds cellulosic biofuels development and authorizes $500 million annually for the production of advanced biofuels that achieve at least an 80 percent reduction in lifecycle greenhouse gas emissions relative to current fuels. Most importantly, the RFS schedules the introduction of advanced biofuels into the fuel supply.

Other U.S. energy policies have provided incentives for ethanol for many years, including a 46 cent per gallon blending credit for U.S. ethanol blenders and a $1 per gallon credit for biodiesel.* There is also a 54 cent per gallon tariff on imported ethanol to protect U.S. producers.

Several factors will shape the role of advanced biofuels in meeting the RFS in years to come. The U.S. Environmental Protection Agency (EPA) must set volume standards each year, and if second-generation production lags, the EPA can lower the mandatory contribution requirements—greatly diminishing any potential advantages. Additionally, the requirements apply only to new biofuel plants. As a result, the 2015 target of 15 billion gallons will be met largely through existing "grandfathered" facilities, and for the most part with corn ethanol.

Moreover, although U.S. policy sets targets for biofuel use, these are not caps on production. If production of corn ethanol continues to be profitable, it will persist above and beyond any minimum RFS requirement. Industry experts predict that U.S. corn ethanol production could eventually amount to more than 30 billion gallons, up from 9 billion gallons in 2008.[64] While the "blend wall"—the percentage of ethanol that by regulation can be blended into conventional gasoline—is at present a barrier to increased use of corn ethanol, this can be eliminated if the EPA decides to raise the percentage from its current level of 10 percent.† In fact, such changes have already been proposed.[65]

If the RFS mandate is to be part of a real solution to U.S. dependence on imported fuels and global warming, it must be re-evaluated in light of changing circumstances. Four broad changes in U.S. policy would make biofuels production more environmentally sustainable and ensure that the use of biofuels for transportation contributes to the global effort to reduce greenhouse gas emissions. These are: developing sustainability standards; advancing biofuels production and new technologies; creating green jobs through biofuels production; and promoting policy coherence.

* Before January 1, 2009 the blending credit was 51 cents per gallon.

† *Oil Market Report's User's Guide and Glossary* defines blend wall as, "A limit to blending [biofuels into conventional, oil-based refined products] due to logistical and infrastructural short-comings or a lack of financial incentive."

The Joint BioEnergy Institute (JBEI) is advancing the development of the next generation of biofuels, liquid fuels derived from the solar energy stored in the biomass of plants such as this switchgrass. JBEI is a San Francisco Bay Area scientific partnership led by Berkeley Lab and including Sandia National Laboratory, the University of California (UC) campuses of Berkeley and Davis, the Carnegie Institution for Science and the Lawrence Livermore National Laboratory.

Photo courtesy Lawrence Berkeley National Laboratory

(1) Developing Sustainability Standards

The RFS requires fuels to meet minimum greenhouse gas emissions reductions to qualify. Corn ethanol, for example, must achieve at least a 20-percent reduction in lifecycle emissions compared to gasoline; biomass-based diesel must achieve a 50-percent reduction; and cellulosic biofuels a 60-percent reduction.[56] Moreover, the EPA is required to reevaluate conditions annually and to adjust emissions requirements by 10 percent if the negative impacts of increased biofuels production on the land or on the economy end up being higher than the benefits. The RFS requires a full lifecycle analysis from the field to the tank, including both direct emissions as well as indirect emissions from changes in land use. The EPA has not yet released standards or methodologies for these calculations, but they are likely to be controversial.

Many industry and environmental groups, as well as the State of California, have started to develop sustainability criteria for second-generation biofuels. In addition to environmental issues, some of these voluntary sustainability criteria also look at social impacts, biodiversity, and legal entitlement to land. The extent to which the EPA is taking into account the criteria being developed in the private sector and elsewhere is unclear.*

California's Low Carbon Fuel Standard calls for a 10 percent reduction in the carbon intensity of transportation fuels by 2020, based primarily on a global warming intensity metric. While this metric would capture many of the environmental parameters associated with biofuel production, it would not capture the social ones such as food price increases, consolidated land holdings, environmental justice considerations, and the effects of climate change on poor populations. This shortcoming could be addressed in part by requiring biofuel providers to report on sustainability issues and by requiring the State of California to report on impacts at the state and global level.

Policy Recommendations:

- Encourage the EPA to work with other agencies, the State of California, and other stakeholders to establish agreed sustainability standards and criteria as soon as possible.

* Office of Management and Budget Circular No. A-119, 2/10/98 encourages federal agency use of voluntary reference standards where appropriate.

- Create incentives for production and use of more-sustainable biofuels by making government support conditional on performance of feedstocks and feedstock producers, rewarding biofuels with the least-harmful lifecycle impacts.
- Adopt a federal Low Carbon Fuel Standard that reduces the carbon content of transportation fuels over time.
- Require corn ethanol and soy biodiesel to compete with second-generation and other advanced biofuels in a race to improve their production and make a lower-carbon product.

(2) Advancing Biofuels Production and New Technologies

Although the new RFS could help make U.S. biofuels development more environmentally sound and economically beneficial, it continues to provide incentives for corn-based ethanol. The corn ethanol industry is no longer an infant industry that needs protection, and the RFS requirements make it difficult to jumpstart the advanced technologies that are needed to supplement this inefficient fuel source.

Possible biofuel: the grass Miscanthus giganteus.
Photo by Pat Schmitz

Several experts have sought to address this problem, including with a proposal to tie the blender credit to the price of corn and to phase it out entirely when corn prices reach a certain level.[67] This would have the advantage of moderating the demand for corn ethanol when prices are high but supplying some incentives when prices are low.

Other experts have called for the elimination of the blender credit for ethanol or for a counter-cyclical tariff reduction to ameliorate adverse effects on U.S. ethanol producers caused by eliminating the tariff altogether. This would result in a lower tariff in months when blenders' needs exceed domestic supply. It could also result in reduced infrastructure and costs associated with transporting ethanol from refineries in the Midwest (where they are close to the feedstock) to the coasts (where most consumers live).

Policy Recommendations:

- Use existing and new economic instruments, such as the blending credits, to spur development of cellulosic and advanced biofuels and phase out incentives for corn ethanol.
- Tie biofuels support to the use of cellulosic or advanced biofuels. For example, the blender credit could be based on performance, with the more sustainable fuels receiving more support. Another possibility is to set a floor for government support that requires lifecycle reductions of at least 50 percent or higher.
- Build on the growing pressure to increase the amount of ethanol that can be blended into fuels by letting blenders who utilize cellulosic and advanced biofuels to be first eligible to use increased percentages of ethanol in fuel blends as the allowable blended amount increases.
- Provide incentives for refineries to stop using coal-fired power, or prohibit funding for coal-fired refineries outright. Increase support for renewable-fired refineries, including for infrastructure and capital costs, and make federal funding for biofuels projects that reach their emission goals only through carbon capture and storage contingent on carbon storage that is proven to be viable and safe.
- Require biofuel farmers to show "cross compliance" with erosion control, sodbuster, and swampbuster programs to qualify for financial incentives and other support.
- Acknowledge production of sustainable biofuels through labeling at the retail level, in much the same way that "green electricity" is treated.
- Identify and incentivize production of non-invasive cellulosic feedstocks on marginal land.

(3) Creating Green Jobs Through Biofuels Production

Several studies on green jobs have included the potential job-creation benefits from producing and refining transportation fuels, including biofuels. As U.S. biofuel production expands beyond conventional large-scale agriculture and into the use of waste materials, there is a shift toward the local and small scale. With interlinked information networks, processing, and distribution capabilities, production can occur at multiple locations, from multiple sources, and with a greater diversity of processes. Indeed, small-scale, local production facilities might prove to be more efficient and able to access feedstocks at lower cost than large ones, especially as transportation distance and costs are cut down significantly.

If energy production is seen as an enterprise that of necessity needs to operate at large scale, it may take a long time for such systems to demonstrate both operational capability and cost viability. But if small-scale, local systems are recognized as having cost and flexibility advantages and can also demonstrate operational viability and consistent quality, then perhaps better biofuels are not as far away as some fear. Biofuels can provide a rather unique developmental advantage to rural and urban communities, and if a local model can prevail for some uses, it would be an important asset to local and regional energy development plans.

Policy Recommendations:

- Rethink scale in the various biofuel industry sectors—including small-scale production and refining capacity. Eliminate minimum production requirements for incentive programs and government support.
- Promote urban and rural biofuel development and spark job creation by focusing on regional and local markets.
- Provide incentives for local and regional government fleets to source a share of their biofuels from cooperatives and other small-scale, local sources.

(4) Promoting Policy Coherence

Biofuel production affects agricultural, energy, environmental, climate change, national security, rural development, and job-creation policies. While the Energy Independence and Security Act touches on many aspects of these related areas, it does not deal with the relative importance of biofuels in a renewable energy portfolio or their long-term significance in U.S. energy use.

Although this report has focused on the use of biofuels for transportation, many experts are convinced that a better use of our finite biomass resources is for electricity and heat production. Not only is bio-based electricity generation more efficient and able to offset coal, it also makes better use of many biomass resources such as wood. Indeed, high heating oil prices spurred the development of a thriving U.S. wood pellet industry, and this will be an important source of energy regardless of how corn prices affect corn ethanol production.

Policy change will be viable only if it is coordinated and if input is sought and received from all stakeholders. This will ensure that biofuels production is not an unwelcome development, but a considerable opportunity to invest in a sustainable energy future.

Policy Recommendations:

- Ensure policy coherence by building a policy function in Congress and the Administration to coordinate and promote a sustainable energy transition that encompasses all sectors, including transport, electricity, and heat.
- Re-examine the renewable energy portfolio balance to bring on cellulosic and other advanced biofuels faster and to promote biomass use for electricity generation and heat.
- Adopt ambitious national renewable energy targets and advanced feed-in laws that make it easier for small producers to sell their surplus electricity into the grid, and set a carbon performance standard for electricity.
- Create a broad transportation policy that looks beyond biofuels to more-efficient vehicles, electric/plug-in vehicles, better urban design, and investments in good public transportation systems and rail.

The costs of increasing corn ethanol production have been felt in food and fuel prices, and prospects are not good for increased investment in more-sustainable fuels absent additional incentives. There is also no guarantee that there will be significant cellulosic production anytime soon and a very large probability that corn ethanol will continue to dominate domestic biofuel production, even though other kinds of biofuels might deliver much greater climate benefits.

The United States has a real opportunity to adjust course and ensure that clean and sustainable biofuels, rather than just more biofuels, are a priority. Experiences of recent years have demonstrated the dangers of pushing blindly for increased biofuel production without considering the unintended consequences. The challenge for a red, white, and green path is to ensure that second-generation biofuels are developed quickly while avoiding the mistakes of the past.

Endnotes

1 F.O. Licht, *World Ethanol and Biofuels Report*, 23 October 2008; U.S. Energy Information Administration (EIA), "Petroleum Basic Statistics," at www.eia.doe.gov/basics/quickoil.html, viewed 15 December 2008. Figure 1 from the following sources: ethanol data for 1990–2007 from Renewable Fuels Association (RFA), "Historic Fuel Ethanol Production," www.ethanolrfa.org/industry/statistics/#A, viewed 10 December 2008; ethanol data for 2008 from F.O. Licht, op. cit. this note; biodiesel data for 1990–2007 from National Biodiesel Board (NBB), "U.S. Biodiesel Demand," January 2008, at www.biodiesel.org/pdf_files/fuelfactsheets/Production_Graph_Slide.pdf; biodiesel data for 2008 from USDA Biodiesel Education Program, "National Biodiesel Board Executive Summary 2003–2008," September 2008, at www.biodiesel.org/usda/pdfs/NBB%20Education%20Program%20Brochure.pdf

2 Figure 2 from U.S. Department of Agriculture (USDA), Economic Research Service (ERS), "Supply and Use: Corn," Feed Grains Database, www.ers.usda.gov/Data/feedgrains, updated 1 December 2008; ethanol estimate for 2008 from USDA, "World Agricultural Supply and Demand Estimates," WASDE-465, 11 December 2008.

3 Ibid.

4 Miguel Carriquiry, "U.S. Biodiesel Production: Recent Developments and Prospects," *Iowa Ag Review*, Spring 2007, pp. 8–9, 11; NBB, "Commercial Biodiesel Production Plants," fact sheet (Jefferson City, MO: 7 September 2007).

5 NBB, "U.S. Biodiesel Production Capacity," fact sheet (Jefferson City, MO: 18 January 2008); NBB customer service, e-mail to Raya Widenoja, Worldwatch Institute, 21 December 2007.

6 Ibid.; NBB, "Production Estimate Graph," www.biodiesel.org/pdf_files/fuelfactsheets/Production_Graph_Slide.pdf, viewed 15 December 2008; RFA, op. cit. note 1.

7 NBB, "U.S. Biodiesel Production Capacity," op. cit. note 5.

8 See, for example, C. Ford Runge and Benjamin Senauer, "How Biofuels Could Starve the Poor," *Foreign Affairs*, May/June 2007.

9 USDA, *USDA Agricultural Projections to 2017* (Washington, DC: February 2008), p. 28.

10 F.O. Licht, op. cit. note 1.

11 Estimate of 12 percent from Jason Hill et al., "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," *Proceedings of the National Academy of Sciences*, 25 July 2006, p. 3; 18 percent from Alexander E. Farrell et al., "Ethanol Can Contribute to Energy and Environmental Goals," *Science*, 27 January 2006, pp. 506–08. Corrected 23 June 2006 (original estimate of 13.8 percent calculated in January 2006 was updated to 18 percent in June 2006 due to new information about emissions from limestone and nitrogen applications); Michael Wang, May Wu, and Hong Huo, "Life-cycle Energy and Greenhouse Gas Emission Impacts of Different Corn Ethanol Plant Types," *Environmental Research Letters*, April–June 2007, p. 12.

12 Sidebar 2 from the following sources: Farrell et al., op. cit. note 11; Wang, Wu, and Huo, op. cit. note 11; John Sheehan et al., "Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol," *Journal of Industrial Ecology*, vol. 7, no 3–4 (2004), p. 138; Worldwatch Institute, *Biofuels for Transport: Global Potential and Implications for Sustainable Energy Agriculture* (London: Earthscan, 2006), p. 209; United Nations Environment Programme, *Global Environment Outlook, GEO-2000* (Nairobi: 2000); Mike Duffy, "Where Will the Corn Come From?" *Ag Decision Maker* (Iowa State University Extension), November 2006; Paul C. Westcott, "U.S. Ethanol Expansion Driving Changes Throughout the Agricultural Sector," *Amber Waves*, September 2007, pp. 13–14; USDA, National Agricultural Statistics Service (NASS), *Crop Production* (Washington, DC: 9 November 2007); Allen Baker, Edward Allen, and Nicholas Bradley, *Feed Outlook FDS-07H* (Washington, DC: USDA, ERS, 14 September 2007), Figure 3, p. 4; Michael Pollan, *The Omnivore's Dilemma* (New York: Penguin Press, 2006), pp. 52–53; Daryll E. Ray, "Agricultural Policy for the Twenty-First Century and the Legacy of the Wallaces," Lecture at John Pesek Colloquium on Sustainable Agriculture, Iowa State University, Ames, IA, 3 March 2004; Dan Charles, "Iowa Farmers Look to Trap Carbon in the Soil," *National Public Radio*, 21 August 2007; Iowa Environmental Council, "Biofuels in Iowa, Policy Advisory Statement" (Des Moines, IA: 26 January 2006), p. 5; U.S. Environmental Protection Agency (EPA), "Table 1.2-4 2006 U.S. Ethanol Production by Energy Source," in "Chapter 1: Industry Characterization," *Regulatory Impact Analysis: Renewable Fuel Standard Program* (Washington, DC: April 2007), p. 13.

13 USDA, "Conservation Reserve Program and Conservation Reserve Enhancement Program," Farm Bill Forum Comment Summary & Background" (Washington, DC: USDA and the Farm Bill Forums, 2006).

14 Jim Giles, "Can Biofuels Rescue American Prairies?" *NewScientist.com*, 18 August 2007.

15 National Research Council of the National Academies (NRC), *Water Implications of Biofuels Production in the United States* (Washington, DC: National Academies Press, 2008), p. 26.

16 World Resources Institute, "Thirst for Corn: What 2007 Plantings Could Mean for the Environment," *WRI Policy Note* (Washington, DC: 2007).

17 Dennis Keeney and Mark Muller, "Water Use by Ethanol Plants: Potential Challenges" (Minneapolis: Institute for Agriculture and Trade Policy, October 2006), p. 4; Joe Barret, "How Ethanol is Making the Farm Belt Thirsty," *Wall Street Journal*, 5 September 2007; "Drought Tightens Grip on Southeast," *Associated Press*, 15 October 2007; NRC, op. cit. note 15, p. 17; Joe Germer, "The Future Is Drying Up," *New York Times*, 21 October 2007; Tom Jones, "Great Lakes Key Front in Water Wars," *Chicago Tribune*, 28 October 2007; Garance Burke, "As Supplies Dry Up, Growers Pass On Farming and Sell Water," *Associated Press*, 25 January 2008.

18 Barret, op. cit. note 17; "Drought Tightens Grip on Southeast," op. cit. note 17.

19 Carey Gillam, "Ethanol Craze Endangers U.S. Plains Water: Report," *Reuters*, 20 September 2007.

20 Martha G. Roberts, Timothy D. Male, and Theodore P. Toombs, *Potential Impacts of Biofuels Expansion on Natural Resources: A Case Study of the Ogallala Aquifer Region* (Washington, DC: Environmental Defense, 2007), p. 3. Worldwatch calculation based on average individual household consumption of 100 gallons of water per day, per Water for Life, 2005–2015, "Factsheet on Water and Sanitation," www.un.org/waterforlifedecade/factsheet.html, viewed 16 December 2008.

21 New Source Review, "Final Changes for Certain Ethanol Production Facilities Under Three Clean Air Act Permitting Programs," fact sheet (Washington, DC: EPA, 12 April 2007).

22 Mark Schwartz, "Ethanol Vehicles Pose Significant Risk to Health, New Study Finds," *Stanford Report*, 18 April 2007; Mark. Z. Jacobson, "Effects of Ethanol (E85) versus Gasoline Vehicles on Cancer and Mortality in the United States," *Environmental Science and Technology*, 18 April 2007, pp. 4150–57.

23 Based on interviews between Raya Widenoja, Worldwatch Institute, and Iowa State professors and extension agents in summer and fall of 2007.

24 See, for example, "State's Ethanol Industry Feels Squeeze of Falling Oil Prices," msnbc.com, 15 December 2008, and Robert Bryce, "Paying the Price for Cheap Oil," *The Guardian*, 30 October 2008.

25 American Coalition for Ethanol, "Ethanol 101," www.ethanol.org/index.php?id=34&parentid=8, viewed 15 December 2008.

26 Dave Swenson, "Determining Biofuels Economic Impacts Considering Local Investment Levels," presentation by the Iowa State University at the Leopold Center Marketing and Food Systems Initiative Workshop, Ames, IA, 6 November 2006.

27 Susanne Retka Schill, "Miscanthus versus Switchgrass," *Ethanol Producer Magazine*, 22 October 2007.

28 Environmental and Energy Study Institute, "Cellulosic Biofuels," fact sheet (Washington, DC: July 2008).

29 Oak Ridge National Laboratory, "Biofuels from Switchgrass: Greener Energy Pastures," http://bioenergy.ornl.gov/papers/misc/switgrs.html, viewed 27 August 2007.

30 Estimate assumes that each bushel yields 2.75 gallons of ethanol, which is roughly the current ratio. The USDA forecast 180 bushels per acre for Iowa the 2007 harvest, per USDA, NASS, *Crop Production* (Washington, DC: 10 August 2007), p. 15.

31 M.R. Schmer et al., "Net Energy of Cellulosic Ethanol From Switchgrass," *Proceedings of the National Academy of Science*, 15 January 2008, pp. 464–69; Nathanael Greene et al., *Growing Energy: How Biofuels Can Help End America's Oil Dependence* (Washington DC: Natural Resources Defense Council (NRDC), December 2004), p. 8; David Tilman, Jason Hill, and Clarence Lehman, "Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass," *Science*, 8 December 2006, p. 1598.

32 See, for example, Humberto Blanco-Canqui and R. Lal, "Soil and Crop Response to Harvesting Corn

Residues for Biofuel Production," *Geoderma*, 15 October 2007, pp. 355–62, and Dan Walters and Haishun Yang, "How Much Corn Stover Can Be Removed for Biofuel Feedstock Without Compromising Soil Quality and Erosion Concerns," presentation at the 2007 Biofuels and Water Resources Mini-Retreat, University of Nebraska-Lincoln School of Natural Resources, Lincoln, NE, 19 January 2007.

33 Martha Groom, Elizabeth Gray, and Patricia Townsend, "Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production," *Conservation Biology*, 28 June 2008, pp. 602–09.

34 Mark Brady et al., "Renewable Diesel Technology," a white paper from the Renewable Diesel Subcommittee of the WSDA Technical Work Group (Olympia, WA: Washington State Department of Agriculture, 25 July 2007), pp. 4–6, 50. Sidebar 3 from the following sources: U.S. Senate Committee on Energy & Natural Resources, "Bipartisan Effort Propels Energy Toward Senate Floor," press release (Washington, DC: 2 May 2007); David Bransby, *Cellulosic Biofuel Technologies*, a report sponsored by the Alabama Department of Economic and Community Affairs through the Southeast Biomass State and Regional Partnership (Auburn, MO: Auburn University, February 2007), pp. 13, 17, 19–21; Jean-Paul-Lange, "Lignocellulose Conversion: An Introduction to Chemistry, Process and Economics," *Biofuels, Bioproducts & Biorefining*, September 2007, pp. 39–48; U.S. Department of Energy (U.S. DOE), Office of Energy Efficiency and Renewable Energy, Biomass Program, "Pyrolysis and Other Thermal Processing," fact sheet (Washington, DC: 13 October 2005); Brad Lemley, "Anything Into Oil," *Discover*, 2 April 2006; Mark M. Wright and Robert C. Brown, "Comparative Economics of Biorefineries Based on the Biochemical and Thermochemical Platforms," *Biofuels, Bioproducts & Biorefining*, September 2007, pp. 49–56.

35 Robert C. Brown, "The Promise of Thermochemical Conversion of Biomass to Biofuels," presentation at University of Nebraska Faculty Retreat, Nebraska City, NE, 15 May 2007.

36 USDA, "Conservation Reserve Program and Conservation Reserve Enhancement Program," op. cit. note 13.

37 See, for example, The Keystone Center, *Field to Market: The Alliance for Sustainable Agriculture Outcomes: Environmental Resource Indicators for Measuring Outcomes of On-Farm Agricultural Production in the United States* (Keystone, CO: September 2008).

38 For example, sweet sorghum as discussed in Martha J. Groom, Elizabeth M. Gray, and Patricia A. Townsend, "Biofuels and Biodiversity: Principles for Creating Better Policies for Biofuel Production," *Conservation Biology*, advance copy 2008.

39 Wang, Wu, and Huo, op. cit. note 11, p. 1.

40 Ibid.

41 Figure 3 from Worldwatch Institute, op. cit. note 11, Table 10.2, p. 162.

42 Ibid.

43 Ibid.

44 Schmer et al., op. cit. note 31; John Jechura, "Maximum Yield of Liquid Fuels from Biomass-Based on Stoichiometry," Technical Memorandum to the National Bioenergy Center (Golden, CO: National Renewable Energy Laboratory, 17 July 2006); David I. Bransby, "Cellulosic Biofuel Technologies," (Auburn, AL: Auburn University, February 2007), Appendix A.

45 Wang, Wu, and Huo, op. cit. note 11, p. 9.

46 Wang, Wu, and Huo, op. cit. note 11 shows an 86 percent reduction in greenhouse gases compared to gasoline; Farrell et al., op. cit. note 11 (June 2006) shows an 88 percent reduction; Schmer et al., op. cit. note 31 shows a 94 percent reduction.

47 Mark Z. Jacobson, "Review of Solutions to Global Warming, Air Pollution, and Energy Security," *Energy and Environmental Science*, advance draft, 1 December 2008.

48 Lew Fulton et al., *Biofuels for Transport: An International Perspective* (Paris: International Energy Agency (IEA), 2004), pp. 61–62; Mark A. Delucchi, Research Scientist, Institute of Transportation Studies (ITS), University of California at Davis, e-mail to Janet Sawin, Worldwatch Institute, 10 March 2006; Mark A. Delucchi, *A Multi-Country Analysis of Lifecycle Emissions from Transportation Fuels and Motor Vehicles* (Davis, CA: ITS, University of California at Davis, May 2005), p. 44; K.H. Lee et al., "Nutrient and Sediment Removal by Switchgrass and Cool-Season Grass Filter Strips in Central Iowa, USA," *Agroforestry Systems*, December 1998, pp. 121–32.

49 Fulton et al., op. cit. note 48; Delucchi, e-mail to Janet Sawin, op. cit. note 49; Delucchi, *A Multi-Country Analysis...*, op. cit. note 48.

50 Lee et al., op. cit. note 48.

51 Bruce A. Babcock et al., "Adoption Subsidies and Environmental Impacts of Alternative Energy Crops," Briefing Paper 07-BP50 (Ames, IA: Iowa State University Center for Agricultural and Rural Development, March 2007); Robert P. Anex et al., "Potential for Enhanced Nutrient Cycling through Coupling of Agriculture and Bioenergy Systems," *Crop Science*, July-August 2007, pp. 1327–35.

52 John Kort, Michael Collins, and David Ditsch, "A Review of Soil Erosion Potential Associated with Biomass Crops," *Biomass and Bioenergy*, April 1998, pp. 351–59; Les Murray and Louis B. Best, "Effects of Switchgrass Harvest as Biomass Fuel on Grassland-Nesting Birds," graduate research project supported by the National Resources Conservation Service and Iowa State University, January 2006, at ftp://ftp-fc.sc.egov.usda.gov/NHQ/ecs/Wild/Biomass.pdf.

53 Global Insight, *U.S. Metro Economies, Current and Potential Jobs in the U.S. Economy*, prepared for the U.S. Conference of Mayors and the Mayors Climate Protection Center (Lexington, MA: October 2008).

54 Robert Pollin et al., *Green Recovery: A Program to Create Good Jobs and Start Building a Low-Carbon Economy* (Amherst, MA: Center for American Progress and Political Economy Research Institute of the University of Massachusetts-Amherst, September 2008).

55 EIA, *Emissions of Greenhouse Gases Report* (Washington, DC: 3 December 2008).

56 Union of Concerned Scientists (UCS), "Senate Energy Bill Establishes Breakthrough Fuel Economy and Fuels Standards," press release (Washington, DC: 13 December 2007); UCS, "Senate Fuel Economy Compromise Delivers Real Benefits," www.ucsusa.org/clean_vehicles/solutions/cleaner_cars_pickups_and_suvs/senate-fuel-economy.html, viewed 18 December 2008. The Senate compromise was the bill version passed into law.

57 Carlo N. Hamelinck, Geertje Van Hooijdank, and André P. C. Faaij, *Prospects for Ethanol from Lignocellulosic Biomass: Techno-Economic Performance as Development Progresses* (Utrecht: Copernicus Institute, November 2003).

58 IEA, *Combined Heat and Power: Evaluating the Benefits of Greater Global Investment* (Paris: 2008), p. 10; Perrin Quarles Associates, Inc., *Review of Potential Efficiency Improvements at Coal-Fired Power Plants* (Charlottesville, VA: 2001)

59 Sidebar 4 from the following: Swedish Ministry of Enterprise, Energy and Communications, "Energy Policy," www.sweden.gov.se/sb/d/5745/a/19594;jsessionid=adrfvK4xe19, updated 25 September 2007; Steve A. Flick, President, Show Me Energy Cooperative, Centerview, MO, interview with Raya Widenoja, Worldwatch Institute, 22 October 2007; Show Me Energy Cooperative Web site, www.goshowmeenergy.com; Dora Guffey, USDA coordinator for The Chariton Valley Biomass Project, supported by U.S. DOE, USDA, Chariton Valley Resource Conservation & Development, Alliant Energy, and Prairie Lands Bio-Products, Inc., interview with Raya Widenoja, Worldwatch Institute, 18 September 2007; Chariton Valley Resource Conservation & Development Web site, www.cvrcd.org; W.E. Mabee and J. N. Saddler, "Wood Energy Policies and Recent Developments in the OECD," Slide 12 in presentation by the Forest Products Biotechnology Department of the University of British Columbia for the United Nations Economic Commission for Europe/FAO Policy Forum, "Opportunities and Impacts of Bioenergy Policies and Targets on the Forest and Other Sectors," Geneva, 10 October 2007; Wang, Wu, and Huo, op. cit. note 11, p. 12.

60 Electric Power Research Institute and NRDC, "Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions, Final Report" (Palo Alto, CA: EPRI, July 2007).

61 EPA, Office of Transportation and Air Quality, "EPA Finalizes Regulations for a Renewable Fuel Standard (RFS) Program for 2007 and Beyond," fact sheet (Washington, DC: April 2007), p. 1.

62 H.R. 6: Energy Independence and Security Act of 2007, Public Law 110-140, signed 19 December 2007.

63 Figure 4 from Bob Larson, "USEPA's Regulatory Action under the Energy Independence and Security Act," presentation on behalf of EPA Transportation and Climate Division, March 2008.

64 Simla Tokgoz et al., *Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets*, Staff Report 07-sr101 (Ames, IA: Center for Agricultural and Rural Development, Iowa State University, July 2007); F.O. Licht, op. cit. note 1; USDA, op. cit. note 9, p. 22.

65 Charles Abott, "Ethanol Makers Push U.S. to Boost Fuel Blend Rate," *Reuters*, 11 November 2008.

66 White House Office of the Press Secretary, "Fact Sheet: Energy Independence and Security Act of 2007" (Washington, DC: 19 December 2007).

67 See, for example, Robbin S. Johnson and C. Ford Runge, "Ethanol: Train Wreck Ahead?" *Issues in Science and Technology* (University of Texas at Dallas), 9 October 2007.

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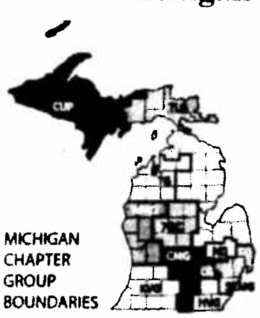

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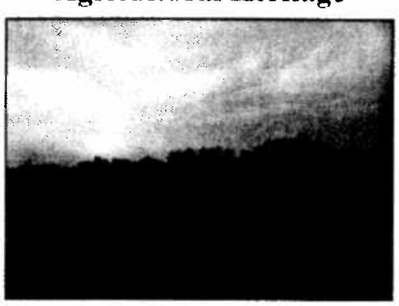
Shared Goals: Michigan's Agricultural Heritage



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